Chapter 06

Lecture Outline*

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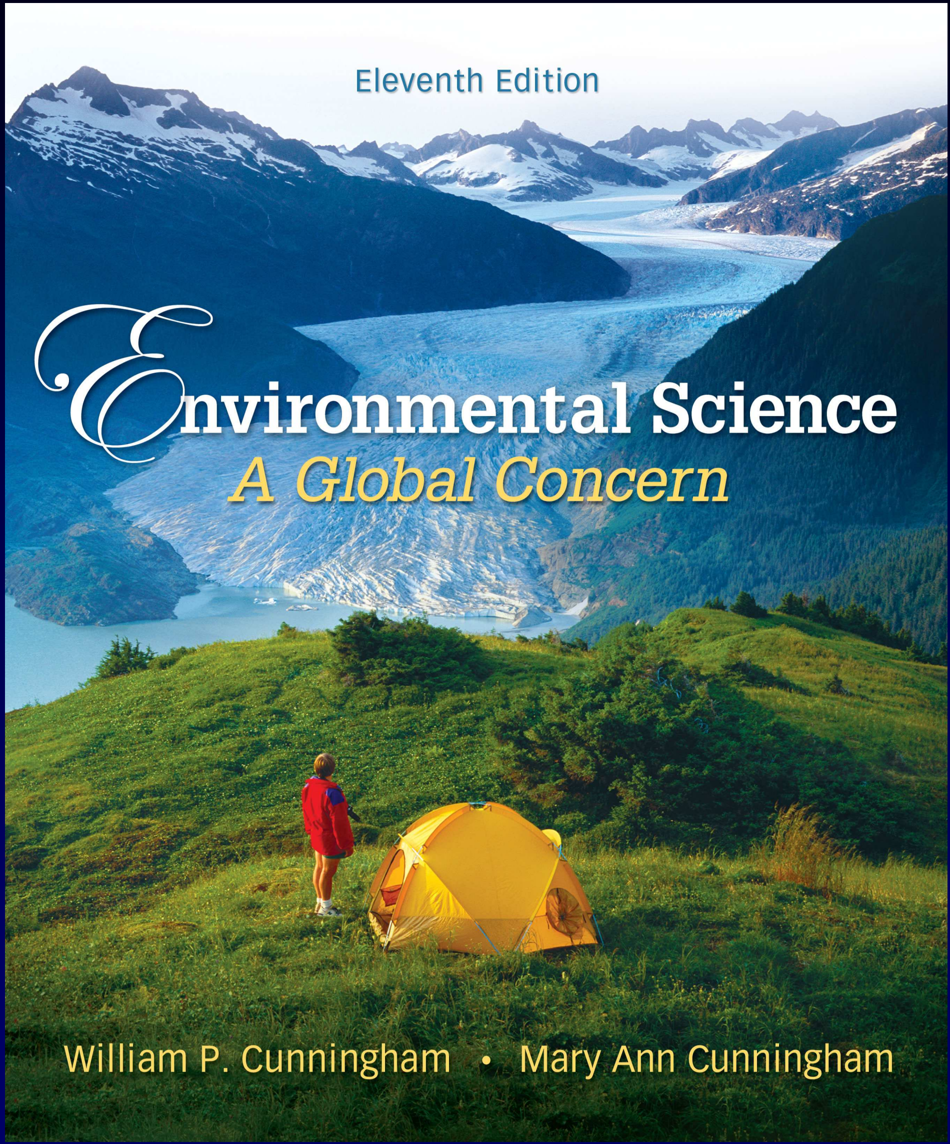

Population Biology

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Outline

- Dynamics of Population Growth
- Factors affecting Population Growth
- Survivorship and regulation of population growth
- Maintaining populations using conservation biology

Biotic Potential

- Biotic potential refers to unrestrained biological reproduction. Biological organisms can produce enormous numbers of offspring if their reproduction is unrestrained.

- Constraints include:
  - Scarcity of resources
  - Competition
  - Predation
  - Disease

Describing Growth Mathematically

- (N) Population – total number of all the members of a single species living in a specific area at the same time.
- (r) Rate—This is the rate of growth; the number of individuals which can be produced per unit, of time under ideal conditions.
- (t)Time—This is the unit of time upon which the rate is based.

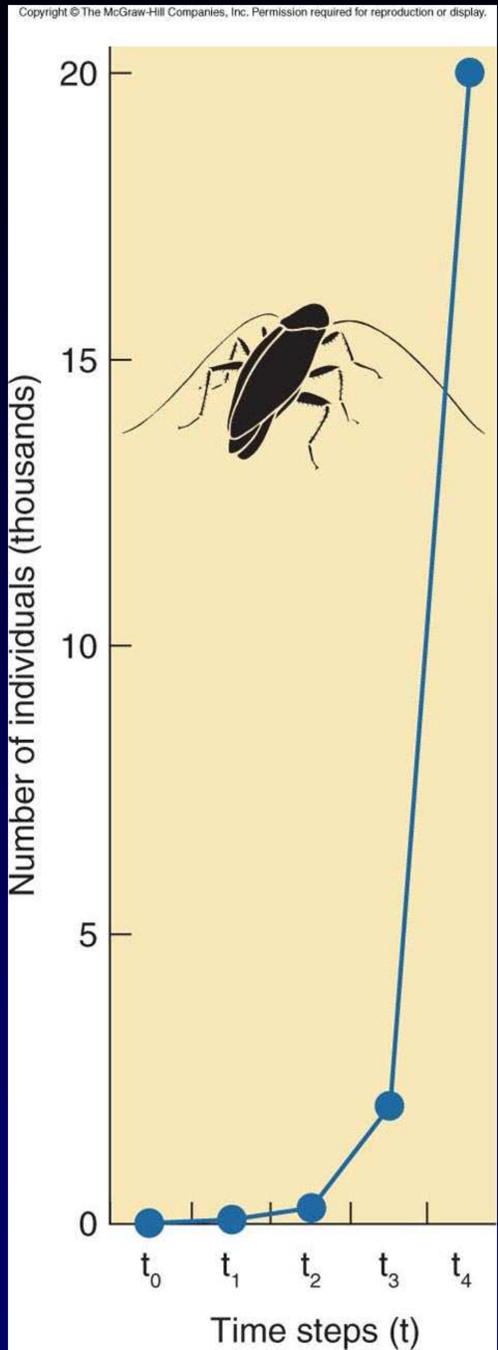
- Geometric Rate of Increase--The population that size that would occur after a certain amount of time under ideal conditions is described by the formula: $N_t=N_0r^t$

Geometric Rate of Increase Example

If cockroaches can reproduce 10 new roaches for each adult roach per 3 month unit of time, the geometric rate of increase would be as follows:

time	N	rate (r)	r x N
t_1	2	10	10 x 2 = 20
t_2	20	10	10 x 20 = 200
t_3	200	10	10 x 200 = 2000
t_4	2000	10	10 x 2000 =20,000

- *Conclusion: 1 pair of roaches can produce a population of 20,000 roaches in 1 year!*



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Number of individuals (thousands)
20
15
10
5
0
t0
t1
t2
t3
t4
Time steps (t)

Exponential Growth Describes Continuous Change

- The previous example projects growth at specific time periods, but in reality, growth in cockroaches under ideal conditions occurs continuously.
- Such change can be described by modifying our previous formula to: dN/dt=rN
- The d is for delta which represents change.
- Thus the formula would read: "the change in the population (dn) per change in time (dt) is equal to the rate of change (r) times the population size (N)."
- This is a simple mathematical model of population showing Exponential Growth.

Rate of increase (r) times number

$$\frac{dN}{dt} = rN$$

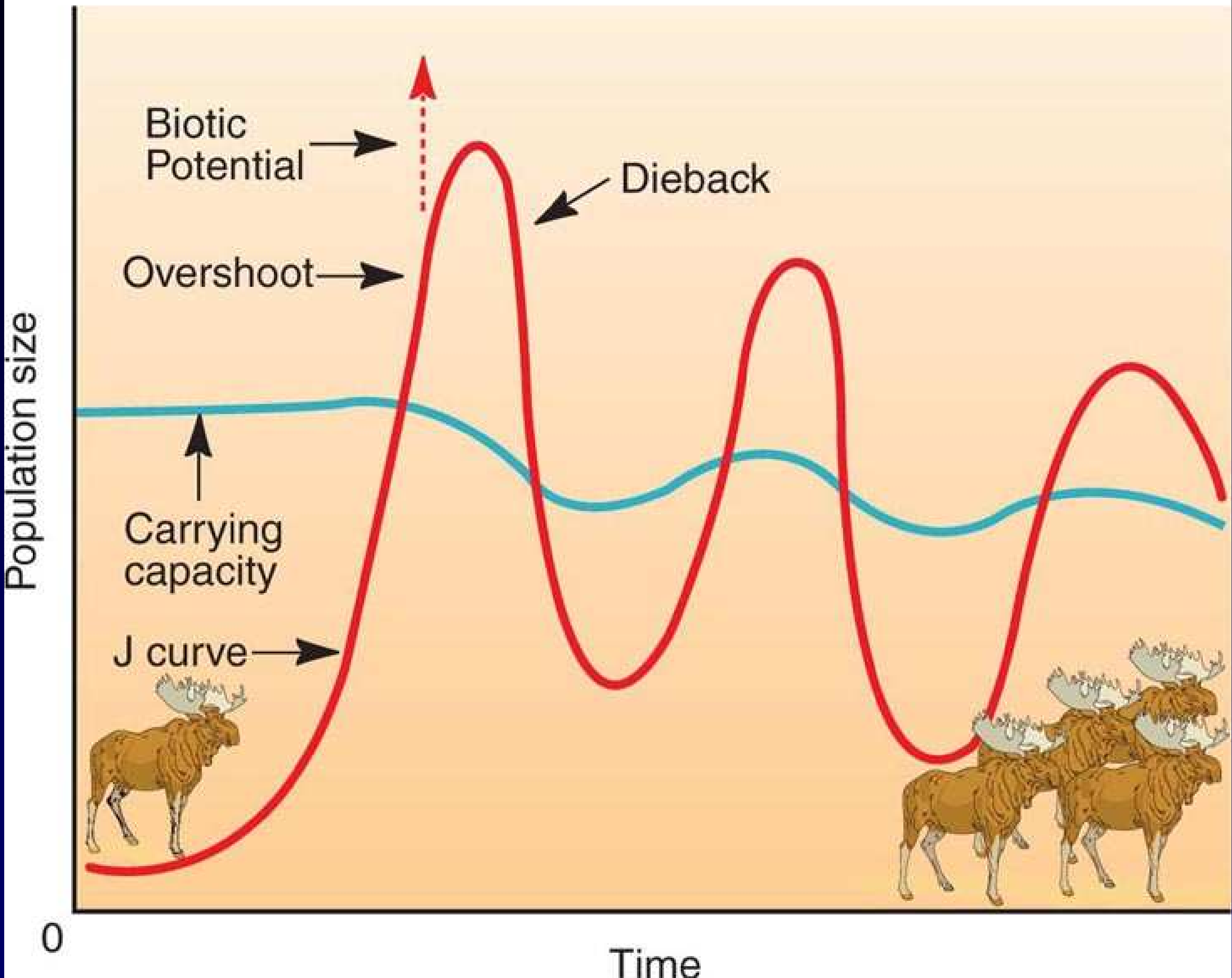
Change in number (N) per change in time (t)

Exponential Growth Always Has Limits

- Exponential growth only can be maintained in a population as long as nothing limits the growth.
- In the real world there are limits to growth that each population will encounter.
- Eventually, shortages of food or other resources lead to a reduction in the population size.

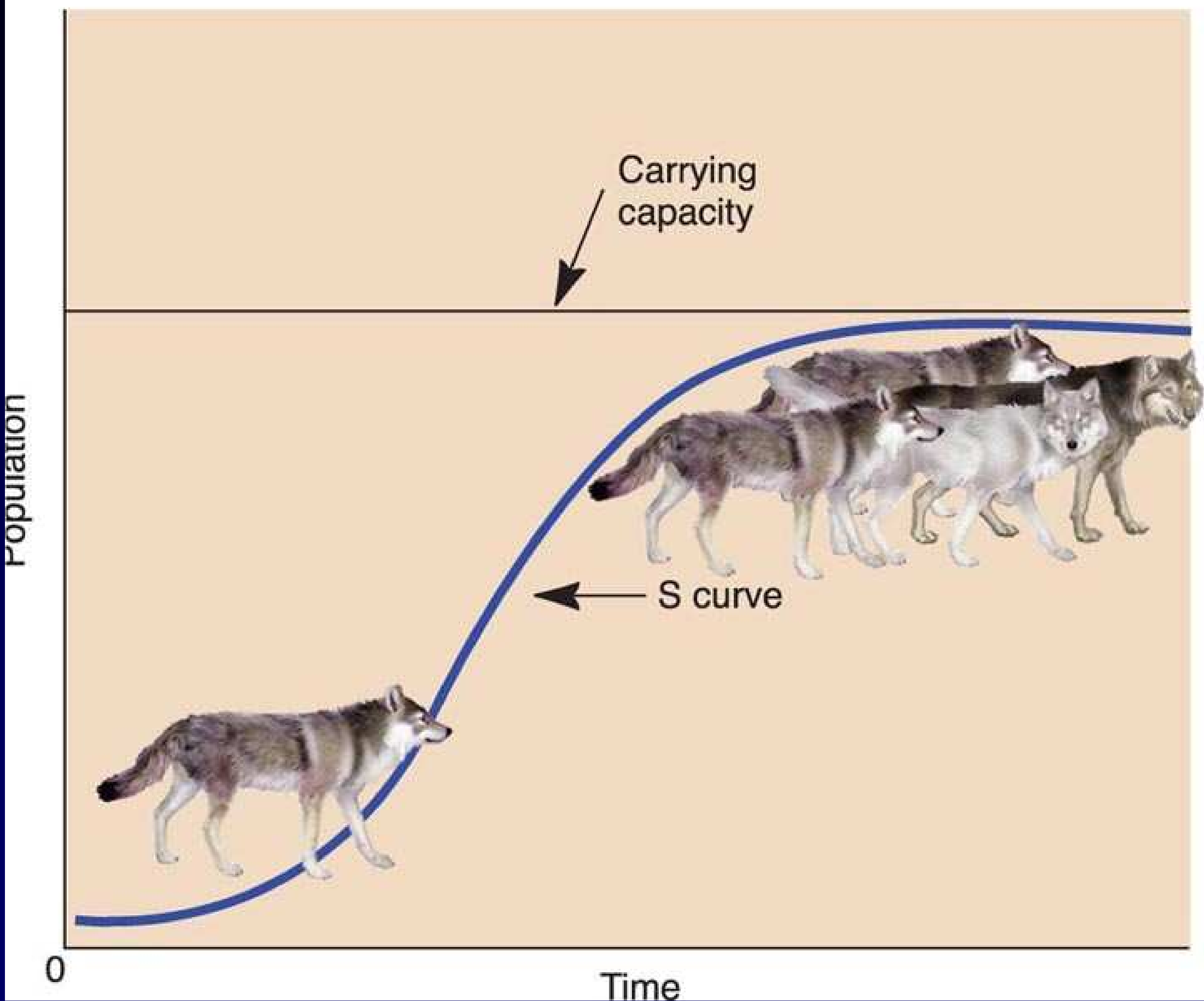
Population Terminology Defined

- Carrying capacity – the population of a species that can be supported in a specific area without depleting the available resources.
- Overshoot – when a population exceeds the carrying capacity of the environment and deaths result from a scarcity of resources.
- Population crash – a rapid dieback in the population to a level below the carrying capacity.
- Boom and bust – when a population undergoes repeated cycles of overshoots followed by crashes.


Biotic
Potential
Dieback
Overshoot
Population size
Carrying
capacity
J curve
0
Time

Resource Scarcity Slows Exponential Growth

- Sometimes population growth slows down as resources become scarce and a population nears its carrying capacity.
- This slowing rate of growth results in an "s-shaped" or sigmoidal growth curve.
- Such growth is also sometimes referred to as logistic growth and can be represented mathematically as: $dN/dt = r N (1 - N/K)$
  - These symbols have the same definitions as before, with "K" being added to indicate the carrying capacity


Carrying
capacity
S curve
Population
0
Time

S-Curve or Logistic Growth

$$\frac{dN}{dt} = rN\left(1 - \frac{N}{K}\right)$$

Population size as a proportion of carrying capacity

Factors Affecting Population Growth

- Logistic Growth is density-dependent which means that the growth rate *depends* on the population density.
- Many density-dependent factors can influence a population including: disease, physiological stress and predation.
- Density-dependent factors intensify as population size increases.
- Density independent factors may also affect populations. These may include drought, fire, or other habitat destruction that affects an ecosystem.

r and K Selected Species

- r-selected species rely upon a high reproductive rate to overcome the high mortality of offspring with little or no parental care. *Example: A clam releases a million eggs in a lifetime.*

- K-selected species have few offspring, slower growth as they near carrying capacity and exercise more parental care. *Example: An elephant only reproduces every 4 or 5 years.*

Reproductive Strategies

Table 6.1 Reproductive Strategies

r-Selected Species	*K*-Selected Species
1. Short life	1. Long life
2. Rapid growth	2. Slower growth
3. Early maturity	3. Late maturity
4. Many small offspring	4. Few, large offspring
5. Little parental care or protection	5. High parental care or protection
6. Little investment in individual offspring	6. High investment in individual offspring
7. Adapted to unstable environment	7. Adapted to stable environment
8. Pioneers, colonizers	8. Later stages of succession
9. Niche generalists	9. Niche specialists
10. Prey	10. Predators
11. Regulated mainly by extrinsic factors	11. Regulated mainly by intrinsic factors
12. Low trophic level	12. High trophic level

Factors That Affect Growth Rates

- 4 factors affect growth rate: Births, Immigration, Deaths and Emigration. (r=B+I-D-E)
- Births –the number of births that occur in the population at any give time; rate of births vary by species and also with stress and food availability.
- Immigration – the number of organisms that move into the population from another population.
- Deaths—mortality, or the number of deaths that occur in the population at any given time, vary by species and with environmental factors.
- Emigration—the number of organisms that move out of the population to another population.

Life Span Vary by Species

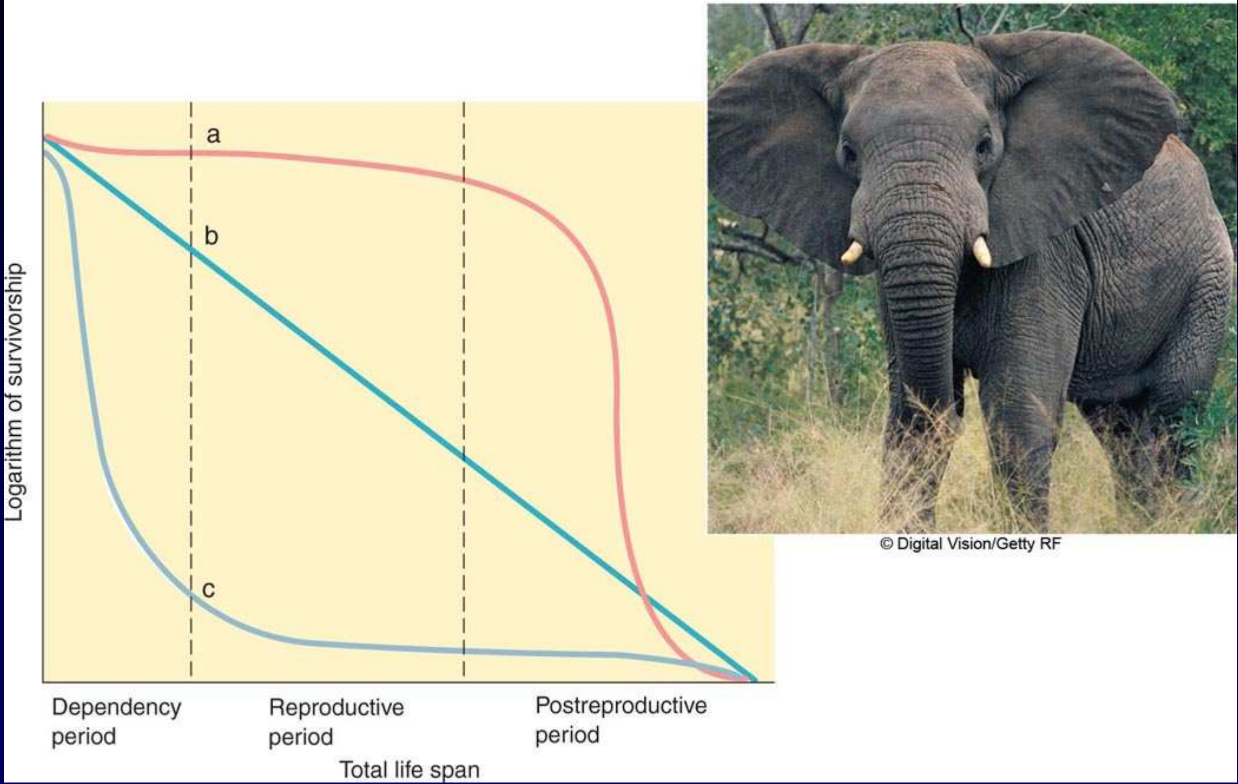
- Maximum Life span - the longest period of life reached by a given type of organism
  - Bristlecone pine live up to 4,600 years.
  - Humans may live up to 120 years.
  - Microbes may live only a few hours.

- Differences in relative longevity among species are shown as survivorship curves.

Survivorship Curve Vary by Species

- Three general patterns:
  - Full physiological life span if organism survives childhood
    - Example: elephants
  - Probability of death unrelated to age
    - Example: Sea gull
  - Mortality peaks early in life.
    - Example: Redwood Trees

Survivorship Curves



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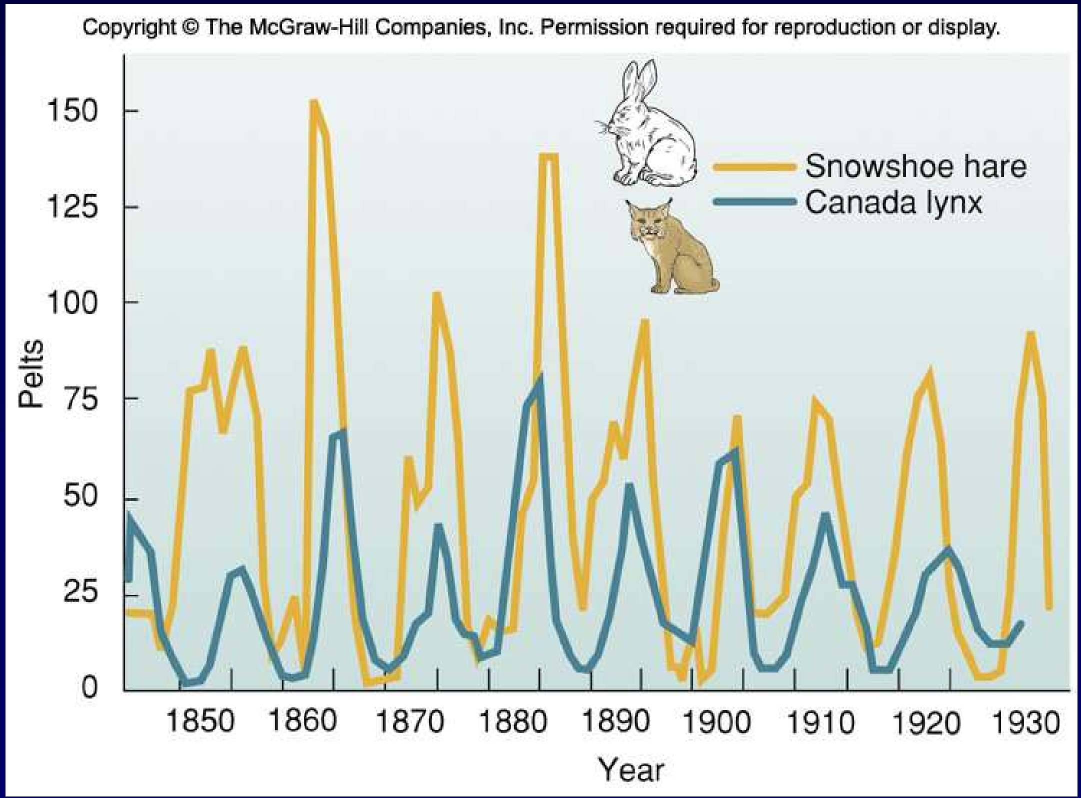
Factors that Regulate Population Growth

- Intrinsic factors - operate within or between individual organisms in the same species
- Extrinsic factors - imposed from outside the population
- Biotic factors - Caused by living organisms. Tend to be density dependent.
- Abiotic factors - Caused by non-living environmental components. Tend to be density independent, and do not really regulate population although they may be important in increasing or decreasing numbers. Example: Rainfall, storms

Density Dependent Factors

- Reduce population size by decreasing natality or increasing mortality.
- Interspecific Interactions (between species)
  - Predator-Prey oscillations



Density Dependent Factors Continued

- Intraspecific Interactions - competition for resources by individuals within a population
  - As population density approaches the carrying capacity, one or more resources becomes limiting.
- Control of access to resources by territoriality; owners of territory defend it and its resources against rivals.
- Stress-related diseases occur in some species when conditions become overcrowded.

Conservation Biology

- Critical question in conservation biology is the minimum population size of a species required for long term viability.
- Special case of islands
  - Island biogeography - small islands far from a mainland have fewer terrestrial species than larger, closer islands
  - MacArthur and Wilson proposed that species diversity is a balance between colonization and extinction rates.

Conservation Genetics

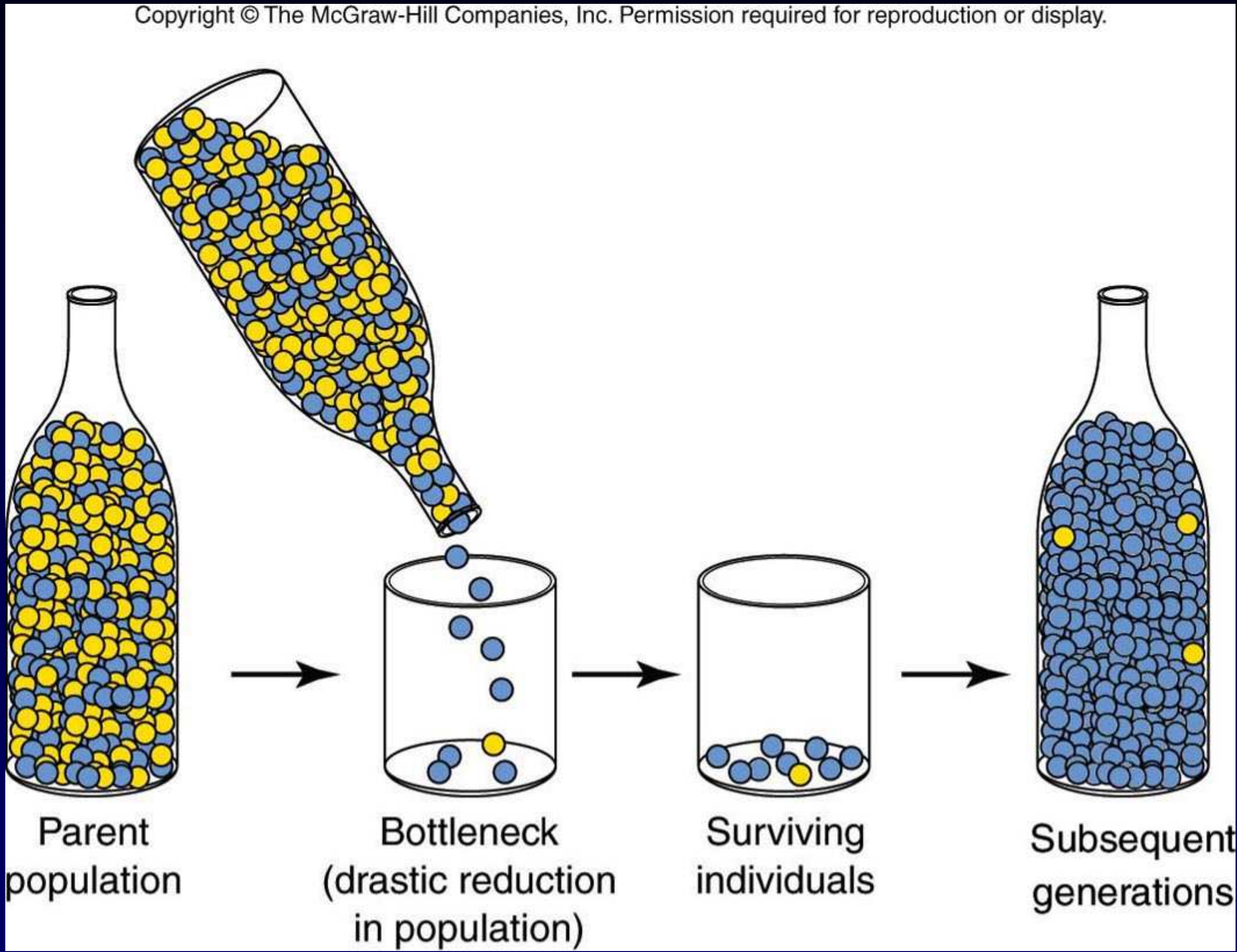
- In a large population, genetic diversity tends to be preserved. A loss/gain of a few individuals has little effect on the total gene pool.
- However, in small populations small events can have large effects on the gene pool.
- Genetic Drift
  - Change in gene frequency due to a random event
- Founder Effect
  - Few individuals start a new population.

Conservation Genetics

- Demographic bottleneck - just a few members of a species survive a catastrophic event such as a natural disaster

- Founder effects and demographic bottlenecks reduce genetic diversity.
- There also may be inbreeding due to small population size.
- Inbreeding may lead to the expression of recessive genes that have a deleterious effect on the population.

Genetic Drift



Population Viability Analysis

- Minimum Viable Population is the minimum population size required for long-term survival of a species.
  - The number of grizzly bears in North America dropped from 100,000 in 1800 to 1,200 now. The animal's range is just 1% of what is once was and the population is fragmented into 6 separate groups.
  - Biologists need to know how small the bear groups can be and still be viable in order to save the grizzly.

Metapopulations are connected populations

- Metapopulation - a collection of populations that have regular or intermittent gene flow between geographically separate units
  - Source habitat - Birth rates are higher than death rates. Surplus individuals can migrate to new locations.
  - Sink habitat - Birth rates are less than death rates and the species would disappear if not replenished from a source.

Metapopulation